MULTI-CRITERIA ANALYSIS (MCA) FOR EVALUATION OF INTELLIGENT ELECTRICAL INSTALLATION

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ABSTRACT

Because the electrical installations are nowadays a lot of options and variants, it is necessary to evaluate these complex installation process from several perspectives and objectively. Due to the complexity of evaluation of electrical installation is design a methodology that uses multi-criteria analysis - MCA.

KEYWORDS: *Intelligent wiring system, Classical wiring system, Economic evaluation*

I. INTRODUCTION

Companies today offer almost the same range of products for intelligent electrical installation, based mostly on three main bus standards – KNX, LON and Nikobus. The basic requirements include operating system installations and lighting, wiring socket, visualization, control heating, cooling and ventilation, control of blinds, awnings, blinds and curtains, windows, doors, gates and gateways, optimizing energy consumption and working with electronic security system and fire signalling. Most companies dealing with electrical installation system offers these features and differ mostly only premium features, price, etc., but the basic idea remains the same - increased comfort, safety and energy saving. [2, 7]

To be selected the best electrical installation, you need to use the appropriate method for evaluation of the alternatives from which to choose - a multi-criteria analysis. However, this method encompass all the criteria under which it would be possible to assess the installation options, it would be appropriate to prepare an independent scientific work or study dealing with the analysis based on a large set of relevant criteria established by experts or a group of designers who are dedicated to design intelligent systems, and conventional wiring. In this study, it would be possible to pay attention to general set of smart wiring, or a classic set where they are both variants of wiring so that it is possible to choose the best option for the specified criteria.

Work is due to clarity divided into smaller units. First introduced to the basic idea of the MCA and is a defined option of electrical installation. For the analysis is selected method - weighted SUM-WSA, which is described in another part of the work. The main part is an analysis of options of the electrical installation using this method and quantitative method of paired comparisons of criteria.

II. MULTICRITERIA ANALYSIS

Multi-criteria analysis (multi-criteria decision making) is selected as one of the options listed in that situation potentially viable options on the basis of large number of criteria.

In addition to formulating a list of indirect objective of the analysis is necessary to have a list of options from which the decision will be selected. This list can be specified explicitly as a final list of options or implied terms of specifications, which must comply with the decision option that could be deemed admissible. [5, 8]

If there is available a list of decision criteria as well as a list of options, it is necessary to consider what form should have the final decision. Multi-criteria analysis basically is instrumental to simulation of decision-making situations in which is defined set of alternatives and group of criterions for evaluation of options. The general procedure involves the MCA at the level of resolution selected five relatively independent steps [5]:

- A purpose-oriented set of evaluation criteria
- Establishment of evaluation criteria weights
- Determine the standard values of criteria weights
- Partial evaluation of options
- Choosing the best option or sorting options

To describe a design methodology for evaluation by the MCA, however, will suffice these defined versions, see. Table 1.

Table 1.Options of electrical installation.

Functions	**Option**			
	A	**B**	**C**	**D**
Installation devices for switching and protection	o	o	o	o
Socket wiring				
Sockets for normal consumption	o	o	o	o
Sockets - Kitchen	o	o	o	o
Sockets with surge protection	o	o	o	o
Lighting control				
Lighting control switching	o	o	o	o
Lighting control dimming	-	-	o	o
Lighting control - PIR detectors	-	-	-	o
Link light on the twilight switch	-	-	-	o
Lighting scenes	-	-	-	o
Control of heating, air conditioning - AHU				
Conventional heating control thermostat	o	o	o	o
Heating control actuators Alpha 0-10V	-	-	o	o
AHU Performance Management	-	-	o	o
Monitoring of emergency conditions AHU	-	-	o	o
Management flue chimney	-	-	-	o
Control of under floor heating according to MRC	-	-	-	o
Ventilation of bathrooms and toilets	o	o	o	o
Control of shutters, blinds				
Shutter control switch	o	o	o	o
Control of external blinds	-	-	o	o
Complete control of external shutters	-	-	-	o
Adjust of lugs	-	-	-	o
Security system, AV systems				
IA (Intruder Alarm)	o	o	o	o
FA (Fire Alarm)	o	o	o	o
Integrated IA	-	-	o	o
Integrated FA	-	-	o	o
TV	o	o	o	o
RF control				
Link to external panel EZS	-	-	-	o
Elect. lock the front door - RF	-	-	-	o
Control garage door - RF	-	-	-	o
User Interface				
Communication with the user via the GSM	-	-	o	o
Managing and monitoring the entire system - SCADA / HMI Reliance	-	-	-	o
Visualization - LCD Touch Panel	-	-	-	o
Software Win Home Server	-	-	-	o

2.1 Determination of standard values of the criteria

Defining of the set of sample values of the criteria usually associated with the term standard. Standard can be understood in two ways:

- detail the nature of the processed object - a model with which they are rated more options compared in order to obtain a copy of this object
- character building - a model solution, the properties are deliberately reduced to the essential properties of an object and these are compared in ratings [9]

2.2. Partial evaluation of options

Evaluation whether an option under consideration meets certain way and to some extent, the desired objectives. The subject of evaluation is the degree of compliance with the objectives considered variants as individual criteria. There are several possible ways and methods to assess the resulting variations. The basic procedure for the partial evaluation is partial evaluation of alternatives and the synthesis of sub-evaluation of options in their overall evaluation. [9]

2.3. Multicriteria evaluation methods

Most methods of multicriteria evaluation of options require cardinal information about the relative importance of criteria that can be expressed using the vector weights of the criteria. The weights of the criteria defined above using the paired comparison of quantitative criteria and subsequent lines of geometric mean. For more extensive processing of multi-criteria analysis of options would be appropriate wiring method as a weighted SUM - WSA. [9]

2.3.1. Method weighted SUM-WSA

Weighted sum method requires cardinal information criterial matrix Y and vector v constructs the weights of the criteria for overall assessment of each variant, so it can be used to search for one best option, and for ordering options from best to the worst. The method of weighted sum method is a special case of utility functions. Reaches a variant according to criteria j ai certain value y_{ij}, brings the user benefits that can be expressed by a linear function of utility. First created normalized criterial matrix R = (r_{ij}), whose elements are obtained from criterial matrix Y = (y_{ij}), using the transformation formula, [5]:

$$r_{ij} = \frac{Y_{ij} - D_j}{H_j - D_j} \qquad (1)$$

In the previous formula, a linear transform criteria values so that $r_{ij} \in \langle 0,1 \rangle$, D_J criteria corresponding to the minimum value in column j a H_j corresponds to the maximum value of the criteria in column j. The pre-conditions is that the criterion to maximize the column j-col.
Criterion matrix Y=(y_{ij}). In this table correspond to columns and rows defined criteria ranked options. The matrix can be written as [5]:

$$\begin{array}{c} \\ a_1 \\ a_2 \\ \vdots \\ a_k \end{array} \begin{array}{c} \begin{array}{cccc} f_1 & f_2 & \cdots & f_k \end{array} \\ \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1k} \\ y_{21} & y_{22} & \cdots & y_{2k} \\ \vdots & & & \\ y_{p1} & y_{p2} & \cdots & y_{pk} \end{bmatrix} \end{array} \qquad (2)$$

When using an additive form of multi-criteria utility function is then equal to the option, [5] :

$$u(a_i) = \sum_{j=1}^{k} v_j \cdot r_{ij} \qquad (3)$$

The option, which reaches a maximum value of utility, u_i is chosen as the best, or can be arranged based on their declining value of the benefits. [5]

2.4. Quantitative method of paired comparisons of criteria

This method uses the so-called Saaty matrix S=(s_{ij}), where i, j = 1,2 ,..., k where s_{ij} represent matrix elements, which are interpreted as estimates of the proportion of weights of the i-th and j-th criterion. The scale is determined by the values 1,2,3 ,..., 9 and the reciprocal values. The corresponding value of the verbal scale:
1 - equivalent to the criteria i and j

3 - slightly preferred the criterion i j
5 - strongly preferred the criterion i j
7 - strongly preferred the criterion i j
9 - absolutely preferred criterion i j
A value of 2, 4, 6, 8 represent intermediate steps. In our case, for simplification, the intermediate stage is unused.
For creation of Saaty matrix we define criteria f_1, f_2 ,..., f_k. Mutual comparison of these criteria, according to the above scale is created by a set of elements s_{ij} Saaty matrix $S=(s_{ij})$. [9]
General registration Saaty matrix [5]:

$$\begin{array}{c} \\ f_1 \\ f_2 \\ \vdots \\ f_k \end{array} \begin{array}{c} \begin{array}{cccc} f_1 & f_2 & \cdots & f_k \end{array} \\ \begin{bmatrix} 1 & s_{12} & \cdots & s_{1k} \\ 1/s_{12} & 1 & \cdots & s_{2k} \\ \vdots & & & \\ 1/s_{1k} & 1/s_{2k} & \cdots & 1 \end{bmatrix} \end{array} \qquad (4)$$

Saaty matrix defined for the analysis of the various wiring options. The sample is designed to create the basic criteria of the matrix and subsequent analysis. [5, 9, 6]

Table 2.Saaty matrix.

	Acquisition costs	**Operating costs**	**Saving energy**	**System maintenance**	**The possibility of heating**	**The possibility of lighting control**	**Reliability**	**Complexity of installation**	**Aesthetics**
Acquisition costs	1	5	3	9	3	3	5	7	9
Operating costs	0,20	1	1	5	3	3	7	3	7
Saving energy	0,33	1,00	1	9	5	5	5	9	7
System maintenance	0,11	0,20	0,11	1	1	1	3	3	7
The possibility of heating	0,33	0,33	0,20	1,00	1	1	5	9	7
The possibility of lighting control	0,33	0,33	0,20	1,00	1,00	1	5	9	7
Reliability	0,20	0,14	0,20	0,33	0,20	0,20	1	9	9
Complexity of installation	0,14	0,33	0,11	0,33	0,11	0,11	0,11	1	5
Aesthetics	0,11	0,14	0,14	0,14	0,14	0,14	0,11	0,20	1

A simple way of determining the weights of the criteria entered from the matrix S consists in calculating the geometric mean of each row of the matrix.

$$g_i = \sqrt[k]{\prod_{j=1}^{k} s_{ij}}\,;\; i, j = 1,2,...,k \qquad (5)$$

Furthermore, the weights are normalized so that the following condition is fulfil, [5] :

$$\sum_{i=1}^{k} v_i = 1; v_i \geq 0 \qquad (6)$$

Standards can be related to, [5] :

$$v_i = \frac{g_i}{\sum_{i=1}^{k} g_i}; i, j = 1,2,...,k \quad (7)$$

III. RESULTS

The above defined Saaty matrices are computed the geometric mean of all lines of standardization and the weights of criteria:

Table 3. Table geometric diameters and weights of criteria.

Criterion	g_i	v_i
Acquisition costs	4,1718	0,303
Operating costs	2,2225	0,161
Saving energy	3,0615	0,222
System maintenance	0,8132	0,059
The possibility of heating	1,2414	0,090
The possibility of lighting control	1,2414	0,090
Reliability	0,5682	0,041
Complexity of installation	0,2842	0,021
Aesthetics	0,1741	0,013
Sum of weights of all criteria	-	1

After defining the weights of criteria should be followed in the analysis of determining the values of standard criteria. Table 3 clearly shows how the distribution of weights for a given selection criteria.

IV. DISCUSSION

However for this is necessary preferably the group of experts as well as more extensive type of scientific work, which would be engaged only in problems of multi-criteria analysis for evaluation of individual options of electrical installation.

V. CONCLUSION AND FUTURE SCOPE

This proposal addresses the use of multi-criteria analysis for comparing the electrical variations based on defined criteria. This methodology is designed for the most part in general because of the possibility of further development in the larger work. This is an outline of options objectively and comprehensively evaluate variants of wiring and help in selecting the most appropriate wiring. Further development work could be focused on the issue of the use of sophisticated methods of choosing a technical solution based on the wiring not only prices but also on many other criteria such as comfort, service, durability, etc. The focus of work should be a discussion of wiring systems from a global perspective where the objective evaluation and selection of a suitable electro-installation is no longer possible to use common approaches, given the magnitude of such systems and their mutual ties. There is some use of the methods of multicriteria analysis (MCA), which would affect the extensiveness of solution and could use the results of this work.

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